

Review

Research Advances in Post-Operative Rehabilitation Following Cochlear Implant

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Abstract Cochlear implantation is a unique method to re-construct audition for patients with severe to profound hearing loss. With increasing clinical application of this technique, its rehabilitative effects in patients has become an important topic of hearing and speech rehabilitation research. This article is an overview of hearing and speech rehabilitative training, rehabilitative efficacy evaluation and factors affecting rehabilitation efficacy following cochlear implantation.

Key words cochlear implant; rehabilitation; evaluation

Cochlear implantation brings about the hope for those patients whose hearing is severely or profoundly damaged. It helps the patient regain audition. However, auditory nerve excitation mechanisms through electrical and acoustic stimulation are different. Auditory nerve excitation by electrical stimulation has a narrow dynamic range, resulting in poor resolution of the intensity and frequency information of verbal stimulation through the cochlear implant ^[1]. In addition, speech perception deficiency in patients with hearing defects can also affect their speech comprehension. Adequate and timely post-implantation hearing and speech training can help patients make the greatest use of their cochlear implants. Studies have shown that speech perception can improve ^[2] and speech intelligibility can also gradually improve in prelingual deaf children after receiving cochlear devices ^[3]. Through evaluation of results of phased rehabilitation education after implantation of cochlear devices, the effects of speech rehabilitation can be assessed, providing guidance for determining surgery indications, defining goals of hearing rehabilitation and

selecting appropriate education programs.

I Hearing and speech rehabilitation education

The WHO defines rehabilitation as the following: apply all useful measures to lighten the influence of disabilities and help the handicapped return back to the society. Hearing disability affects speech and language development in children. Therefore, rehabilitation of deaf children is important and with specific goals. Amplified audio devices and cochlear implants can be used in addition to utilization of other compensatory sensory inputs such as hearing, vision, and proprioception to help deaf children develop language skills based on appropriate use of auditory cues as well as other sensory inputs and correct articulation. In addition, it is also necessary to enable them to reach and maintain their optimal physical, intellectual, psychological and social function levels to prepare for their successful return back to the mainstream society.

1 The model of rehabilitation education

Both the uniqueness of cochlear-implant children and their commonness with the normal-hearing children must be taken into consideration in their rehabilitation education. "Combination of medicine and education" is the basic principle in special education, and is also the principal model of postoperative rehabilitation education for cochlear-implant children ^[4]. The rehabilitation

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education includes three aspects, i.e. auditory rehabilitation, speech rectification and language education. The combination of medical and educational rehabilitation is superior to the language auditory-verbal approach alone. Auditory rehabilitation focuses on auditory detection and identification and comprehension of open and close-set sentences. Speech rectification contains pronunciation preparation and speech pronunciation training. And language education includes learning of vocabularies, sentences, sections and chapters^[5].

2 Auditory-verbal approach

The cochlear implant can help pediatric patients achieve auditory rehabilitation. Post-cochlear implantation auditory training is an important step in language rehabilitation. The auditory-verbal approach requires integrating the training into daily life and focuses on the initial development of audition independent of lip-reading. There are 8 stages in audition development, i.e., auditory detection, auditory attention, auditory orientation, auditory memory, auditory discrimination, auditory selection, auditory feedback and auditory conception^[6]. For children at 2-3 years, the ideal rehabilitation approach is to insist on the auditory-verbal approach with listening as the core. In older children, pronunciation training is necessary to strive for having them catching up with the normal peers^[7].

II Evaluation of the efficacy of audition and speech rehabilitation

1 Evaluation of the efficacy of auditory rehabilitation

Speech audiometry uses speech signals as the stimulating sound to evaluate the speech detection threshold and to determine speech identification. Language is an important communication tool for human beings. Compared with other auditory function tests, speech audiometry reveals defects in speech information communication and reflects the actual auditory disability the patient experiences in his daily life^[8].

1.1 Evaluation of auditory capability in adults

Speech perception evaluation in adult patients includes the differentiation between phonemes and monosyllable words and vocabulary comprehension^[9]. Commonly used English testing materials^[10] include the CID(Central Institute for the Deaf) Everyday Sentences, the Northwestern University Auditory Test

No. 6(NU-6), the Minimal Auditory Capabilities Test(MAC), the Consonant-Nucleus-Consonant Test (CNC), and the Hearing in Noise Test(HINT). The most commonly used Chinese evaluation tool at this time is the minimal auditory capabilities in Chinese (MACC)^[11].

1.2 Evaluation of auditory capability in children

1.2.1 Uniqueness in the evaluation of speech function children's

Speech audiometry in children going through speech development has its unique requirements and its results can be affected by a number of factors^[12]. The patient internal factors include the age, vocabulary size, capability to comprehend and learn, and behavioral maturity. Co-existing diseases or disabilities and other special situations are also considered internal factors that can affect successful administration of speech audiometry in a child. The external factors contain the reaction mode design in the course of testing, skills of testing staff, etc. The appropriateness of test materials, sound delivery, test reaction designation, test results analysis methodology and other factors also need to be taken into consideration when interpreting speech audiometry in children.

1.2.2 Materials for speech audiometry in children with cochlear implants

Multiple materials are frequently used for speech audiometric tests in children with cochlear implants. The Phonetical Balanced Kindergarten List(PB-K)^[13] contains monosyllabic words that are compiled according to the principle of phoneme balance. The Word Intelligibility by Picture Identification(WIPI)^[14], featured by picture identification, is applicable to children with limited vocabularies and restricted ability to comprehend. The Pediatric Speech Intelligibility Test (PSI)^[15] is used in children at an age of about 3 years and also uses picture identification. The Sound Effects Recognition Test(SERT) and the Auditory Numbers Test (ANT) can be used to evaluate auditory function in children who have adopted non-speech communication in daily life. The Meaningful Auditory Integration scale/the Infant- Toddler Meaningful Auditory Integration Scale(MAIS/IT-MAIS)^[16] and the Categories of Auditory Performance(CAP)^[17] are parental questionnaires separately compiled by the Indiana University School of Medicine and the Nottingham Center for Children's Cochlear Implants.

Because the speech comprehension capability of each individual child is different, the materials used for

speech audiometry in a particular child must be appropriate for his/her levels of development. A set of testing methods suitable for children of different ages is required to avoid the maximum and minimum effects. The Speech Identification Testing Grades for Children is usually adopted^[18] in evaluating auditory capability in children with cochlear implants. Other materials often used in the clinic are the CID(Geers, 1994), the IU Kirk (Indiana University School of Medicine, 2000) and the CDaCI(Childhood Development after Cochlear Implantation)^[19].

Compared with English, the Chinese language has its own features in the distribution locations of phonemes among syllables and words and in their combination forms. Test materials used to estimate the auditory perception level independent of language differences, such as SERT, ANT, LING'S Five Phonemes Test and CAP, and MAIS/IT-MAIS questionnaires, can be directly used in China after translation. However, speech audiometry materials related to the evaluation of language levels need to be analyzed individually. Mature English testing materials are unlikely to be appropriate for direct use in Chinese populations.

The evaluation materials often used in China are the Chinese Speech Recognition Series Vocabulary Table for Children and the Hearing and Speech Evaluation Vocabulary Table for Deaf Children's Rehabilitation, both written by Sun Xibin. The vocabulary tables are compiled according to Learning to Speak(a textbook used in schools for the deaf) and follow the principle of phoneme balance. The main form of communication is through pictures (e.g., digital identification), and the content includes,speech recognition, tone recognition, monosyllabic word recognition, dissyllable word recognition, trisyllable word recognition and phrase identification. The test is conducted in the form of a game^[20]. At this time, through in-depth studies on the unique characteristics of the Chinese language, combined with an understanding of the actual environment surrounding Chinese hearing-impaired children, MESP, LNT-M, MLNT-M, MHINT-C and other speech audiometry materials have been or are being developed for use in the clinic.

2 Evaluation of language rehabilitation

The “gold standard” in evaluating language capability is the language development indicators in normal children of appropriate ages, representing the

so called “language age”. Appropriate testing reveals a deaf child's language development level and his equivalent language age relative to normal peers. The assessment also provides information regarding whether a deaf child's language development is well balanced, which facilitates adoption of corresponding measures in the rehabilitation training. There are six indicators: speech clarity, size of vocabularies, length of successfully imitated sentences, image identification on auditory cues, picture description, and dialogue on an age-appropriate topic. These are used to determine the child's levels of pronunciation, vocabulary, grammar, speech comprehension, verbal expression and interactive communication^[21].

In addition, the Meaningful Use of Speech Scale (MUSS)^[22] and the Speech Intelligibility Rating (SIR)^[17], separately compiled by the Indiana University School of Medicine and the Nottingham Center for Children's Cochlear Implants, can also be used to evaluate the speech capability of Chinese patients. The former is used to determine the speech-language development level, vocalization, communication and use of oral language in children, thus evaluating the speech expression capabilities. The latter is applicable to a wide range of age and can be used for long-term follow-up and for monitoring speech generation process in patients with cochlear implants. Speech intelligibility in patients is rated based upon the understandability to listeners to their spontaneous speech, and upon the intuitionistic rating by close contact persons in patients' living environment.

III Factors affecting auditory and speech rehabilitation efficacy

The acquired open speech ability after cochlear implantation is the most important indicator of successful implantation. The course of acquiring such ability is often affected by many factors. Studies have shown that the following factors are likely to affect auditory and speech rehabilitation efficacy in cochlear implant users.

1 Age of deafness onset, age of cochlear implantation and duration of hearing deprivation

In as early as 1988, Tong^[23], through comparing post-operative speech perception in 3 prelingual and 2 postlingual deaf children with cochlear implants, suggested that speech function in prelingual deaf children is poorer than in postlingual deaf children. However, as device use time extended, speech function

in prelingual deaf children gradually improves. The explanation for this observation is the long time lack of auditory experience and subsequent lack of afferent auditory stimulation and, consequently, inadequate morphologic and physiological development of neural structures along the auditory pathway in prelingual deaf children. For this reason, auditory compensation and/or audition reconstruction should be accomplished as early as possible in hearing-impaired children to minimize impacts on hearing and speech development by hearing loss during this important time of language development. Restoring hearing can also resume afferent stimulation to the auditory system, advancing the normal development of neural structures along the auditory pathway, which in turn may facilitate optimal post-operative results. Large sample studies have confirmed this conclusion and indicated that younger patients and patients with later onset deafness show better post-operative results. Also, patients with shorter hearing deprivation duration improve more quickly in post-operative audition^[22-24].

2 Residual hearing and pre-operative use of audiophone

Studies^[25-27] suggest that children who have residual hearing and/or wear audiphones before cochlear implantation enjoy partial auditory stimulation, which may help preserve development of the auditory system. Under the influence of these positive factors, patients can better adapt to the cochlear devices after implantation, which will help them develop post-operative open speech ability. Through well-organized post-operative speech training, improvement of speech recognition in these patients is usually satisfactory.

3 Communication mode

Somers^[28] studied factors influencing the language ability in 68 prelingual deaf children after cochlear implantation, and believed that post-operative performance in children using sign language was poorer than in those using spoken language for communication. Waltzman^[29] confirmed that children using sign language for communication showed poor language-comprehension and slow speech improvement.

4 Other factors affecting post-operative rehabilitation^[30] include sex, size and income of the family, expectation by the patients and parents, coding strategy of the used language and participation in speech therapy after the surgery.

IV Current status and future

Timely and well-doctrined hearing and speech training after cochlear implantation is the key to audition reconstruction and returning patients back to the mainstream society. Chinese is a tonal language and has its own unique features compared with English. Consequently, administration and evaluation of post-operative rehabilitation in Chinese populations and factors that affect this process are unique. Through joined efforts by the Chinese philologists, audiologists and otolaryngologists in their intensive studies on characteristics of the Chinese language and on speech functions in the hearing-impaired population in China, progress is being made both in post-operative rehabilitation in Mandarin-speaking patients and evaluation of its efficacy. In addition, long-term follow-up on cochlear-implant users is underway in an attempt to identify factors that affect audition reconstruction, speech identification, cognitive behaviors and psychological performance after cochlear implantation. This will provide new research directions and a theoretical foundation that will be important to advancing cochlear implantation research in China.

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